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ABSTRACT

This agriculture extension service publication from Pennsylvania State University discusses techniques and equipment used in spraying field crops. In the discussion of field hydraulic sprayers, specific topics include types of sprayers, tanks, pumps, pressure regulators, hoses, boom spraying, directed spraying, and nozzle bodies. In the discussion of weed sprayer operation, specific topics include sprayer calibration, useful formulae, cleaning sprayer, storing sprayer, and common sprayer troubles. In the third section of this publication, the discussion of air blast sprayers, specific topics include air blast spraying for row crops, operational procedures for air row crop sprayers, and sprayer calibration. (MR)

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# FIELD HYDRAULIC AND AIR-BLAST SPRAYERS FOR ROW CROPS

Controlling the application rate..... 1
Types of sprayers..... 1
Tanks..... 2
Suction strainers..... 4
Pumps..... 4
Line strainers..... 6
Pressure regulators..... 6
Pressure gauge..... 6
Selector and shut-off valves..... 7
Hoses..... 7
Boom spraying..... 8
Band spraying..... 8
Directed spraying..... 9
Nozzle bodies..... 9
Nozzle screens..... 12
WEED SPRAYER OPERATION
Sprayer calibration..... 12
Useful formulae..... 14
Operating precautions..... 15
Cleaning the sprayer..... 15
Storing the sprayer..... 16
Some common weed sprayer troubles..... 17
AIR BLAST SPRAYERS
Air blast spraying for row crops..... 19
Operational procedures of air row crop sprayers..... 20
Sprayer calibration..... 22

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SE 024 724

## FIELD HYDRAULIC SPRAYERS

## CONTROLLING THE APPLICATION RATE

It is important to understand the factors affecting the rate at which the chemical is applied. The amount of spray material applied to an acre can be changed by changing the forward speed, the volume of liquid delivered by the nozzles, or both.

### THE FORWARD SPEED OF THE SPRAYER

Any variation in forward speed changes the number of gallons of spray material being applied to an area. If the forward speed is doubled, the nozzles will have only half the time to spray the material. The application rate in gallons per acre (gal/A) is then reduced by half.

The importance of maintaining a constant forward speed, uphill or downhill on soft or hard soil cannot be overemphasized.

Many tractors are now equipped with a speedometer. Unfortunately, the tractor speedometer does not indicate the exact forward speed if there is any drive-wheel slippage. A low-speed farm speedometer available at many automotive supply stores, is a useful addition to any sprayer. This type of speedometer can be activated by a front tractor wheel or by a wheel of the sprayer, and constant forward speed can be maintained, even when spraying hillsides.

### THE VOLUME OF LIQUID DELIVERED BY THE NOZZLES IN GALLONS PER MINUTE (gal/min)

The volume of a liquid or suspension delivered by the nozzles is determined by:

(1) the size of the opening at the nozzle, and
(2) the pressure of the spray solution at the nozzle.

The size of the opening in the nozzle is closely controlled when the nozzle is manufactured. However, as the nozzle is used, this opening becomes enlarged and the quantity of spray material delivered increases. Wettable powder suspensions cause the opening in a brass nozzle to enlarge rapidly. If brass nozzles are used to spray wettable powder suspensions, they should be re-calibrated after 30 to 50 acres have been sprayed.

The pressure of the spray material at the nozzles is controlled by the pressure regulator. If for any reason the pressure changes, the application rate in gal/A will change. Suppose that a sprayer has been used at a low pressure of 30 pounds per square inch (psi) and that the operator decides to use 90 psi on the next job: the sprayer must be calibrated at the 90 psi pressure to determine the new application rate.

## TYPES OF SPRAYERS

### TRAILER MOUNTED

This type of sprayer is quickly and easily attached to the tractor. The trailer wheels should be adjusted to track with the tractor wheels.

Trailer-mounted sprayers usually have a 100- to 300-gallon tank. This type of sprayer should be used when large acreages are to be sprayed, the source of water is not close at hand, or the land is too hilly to mount the tank on the tractor.

FULLY MOUNTED

This type of sprayer is very maneuverable, and extremely useful in small, irregularly shaped fields.

(1) Tank at the rear: The sprayer can be easily attached to the tractor. However, the tank usually cannot hold more than 100 gallons if tractor stability is essential.

(2) Center-mounted saddle tanks: This type of sprayer takes a long time to attach to the tractor. With the boom mounted in front of the tractor, it is easy for the operator to see when the nozzles become plugged. Since the drums are mounted horizontally, satisfactory agitation of the spray solution is more easily obtained than when the drums are mounted vertically.

## TANKS

The ideal sprayer tank should be:

(1) Made of a material or combination of materials that will never rust or corrode no matter what chemical is put in it.

(2) Shaped in such a way that proper agitation of the spray material can be easily obtained.

(3) Strong, rigid, and durable so that it can withstand the rough usage it will receive in the field.

(4) Light in weight.

(5) Equipped with at least a 12-inch-square splash-proof screened opening.

(6) Easily cleaned and drained.

(7) Low in cost.

Steel, stainless steel, plastic-coated steel, plastic reinforced with fiber glass, and aluminum alloys are the most commonly used materials for sprayer tanks. Stainless steel, plastic-coated steel, plastic reinforced with fiber glass, and aluminum alloy are superior to ordinary steel tanks because they are rust and corrosion resistant. These tanks are more expensive. The operator must be extremely careful not to break the plastic coating on a plastic-lined steel tank.

The most common tank is a 55-gallon drum. When the drum is vertical (two holes at the top) the overflow line from the pressure regulator should deliver the spray material to the bottom (not the top) of the tank. The 55-gallon steel drum is the least expensive sprayer tank available. However, ordinary steel drums rust and corrode rapidly, do not have an opening large enough to conveniently add wettable powders to the tank, and the sharp corners in the bottom of the drum make adequate agitation of the wettable powder suspensions almost impossible.

Sprayer tanks should be equipped with a coarse screen in the filler opening. This screen is essential to prevent large lumps of wettable powders, pieces of wood, or debris from entering the tank. A satisfactory filler screen can be made from a fly screen.

If the tank does not have a gauge to indicate the number of gallons in the tank, a measuring stick can be made (with 5-gallon graduation marks) for determining the quantity of chemical that must be added to a partially filled tank, as well as for aiding in calibrating the sprayer.

## AGITATION

Adequate agitation of the spray material in a sprayer tank is essential to ensure that the same quantity of chemical is applied regardless of how full the tank is. The amount of agitation required varies with the shape of the tank and the type of chemical (soluble or insoluble) used.

### THE EFFECT OF TANK SHAPE

The spray material in the tank can be agitated hydraulically with spray material from the by-pass line, or mechanically with a series of paddles on a shaft. If the tank has a flat bottom, the spray material in the tank will require 30 to 40 percent more agitation than the spray material in a round-bottom tank.

### AGITATION OF CHEMICALS IN SOLUTION(2,4-D, etc.)

These chemicals can be agitated satisfactorily by the overflow from the pressure regulator. The by-pass line should carry 10 to 15 percent of the boom output when the nozzles are operating, and should deliver the liquid to the bottom of the tank (not the top) for most effective agitation and the least amount of foaming.

### AGITATION OF CHEMICALS IN SUSPENSION (atrazine, etc.)

Orchard sprayers have satisfactorily handled wettable powder suspensions for many years. Almost all orchard sprayers have a shaft with one or more paddles on it to mechanically agitate the wettable powder suspension in the tank. Mechanical agitation should also be used to keep wettable powder herbicides in suspension in a weed sprayer tank.

Many weed-sprayer tanks cannot be conveniently equipped with a mechanical agitator. The by-pass line from the pressure regulator will not supply a sufficient volume of liquid to keep a wettable powder in suspension in the tank. Since four to seven gallons per minute (gal/min) are required to keep the wettable powder in suspension, it is essential that an agitator line be connected to the pressure side of the pump. This line should deliver the liquid to the bottom of the tank. If an "agitator nozzle" or other nozzles are attached to this agitator line, the effectiveness of this agitation method is increased.

Bilge pumps, designed to pump water out of small boats, can be used to agitate the herbicide in the sprayer tank. They are small centrifugal pumps driven by 6- or 12-volt (DC) electric motors. If the motor is sealed, the entire bilge pump can be submerged in the sprayer tank. These pumps have sufficient capacity and durability to provide adequate agitation for chemicals in suspension.

## SUCTION STRAINERS

The suction strainer is in the sprayer system to protect the pump by filtering out scale and rust flakes as well as other debris in the sprayer tank. This suction strainer should have a 100-mesh monel or stainless steel screen when wettable powders are used. The greater the surface area of the screen, the greater is its filtering capacity. A suction strainer with a large filtering capacity will not plug as frequently as one with a small filtering capacity.

If the suction strainer is outside the tank, a shut-off valve should be located between the strainer and the tank. This valve will allow the operator to clean the strainer without first emptying the tank.

## PUMPS

The ideal sprayer pump should deliver the required volume of spray material at the required pressure, and should have a long life no matter what material it is pumping. It should also be dependable, easy to maintain, corrosion resistant, and inexpensive. Unfortunately, most pumps available for sprayers today cannot be considered ideal pumps.

The capacity in gal/min of a new sprayer pump is affected by the speed at which it is driven as well as by the pressure against which it is pumping. As the pump speed increases, the capacity of the pump increases. As the pressure against which the pump is working is increased, the capacity of most pumps is decreased. Most pump manufacturers have a pump performance table in their advertising literature which shows the effect of pump speed and sprayer pressure on the capacity of the pump. These performance tables must be consulted to compare the capacity of one pump with another, since there is no standard pump speed or sprayer pressure.

WARNING--Never operate a sprayer pump at speeds or pressures above those recommended by the manufacturer.

The two general kinds of pumps used on weed sprayers are the positive and the nonpositive displacement type. At present, there are more of the positive displacement types of pumps in use on weed sprayers.

### TYPES OF POSITIVE DISPLACEMENT PUMPS

The external gear pump is the lowest-priced pump, but only one or two manufacturers make models that will accomodate abrasive wettable powder suspension. Any external gear pump is satisfactory for chemicals in solution if it is large enough to supply the boom and the extra liquid required for agitation in the tank.

The internal gear pump is in the same price range as the external gear pump. Some internal gear pumps are made of materials sufficiently durable to accomodate wettable powder suspensions.

The roller pump is perhaps the most commonly used sprayer pump. The five to eight rollers are made of nylon or a type of rubber. The rubber rollers are more expensive than the nylon and are more durable when abrasive wettable powder suspensions are pumped. Unfortunately, replacing the rollers does not always restore the pump to its original condition because the wettable powders may wear the pump housing or the roller groove in the pump rotor.

The piston or plunger pump has been used successfully for many years in orchard sprayers. Several manufacturers make power take-off mounted piston pumps. Piston pumps, particularly those with nylon fabric or leather piston cups instead of metal piston rings, are abrasion resistant and accomodate wettable powder suspensions satisfactorily. Piston pumps are available with one, two, or four cylinders. Most piston pumps have an air chamber incorporated in the pump casting to smooth out the surges in the pressure lines and to stop the pressure gauge needle from jumping. If the pressure gauge needle jumps so that it cannot be read, a separate air chamber or surge tank should be installed on the pressure side of the pump.

The diaphragm pump is considered abrasion resistant because the liquid being pumped does not come in contact with any moving metal parts (except the pump valves). It is important to consult the manufacturer's recommendations before using a new chemical; some chemicals may cause the diaphragm to deteriorate rapidly. The diaphragm pump is usually sold with a separate air chamber because the pump may not have one.

WARNING--Never operate any of these positive-displacement types of pumps without a by-pass pressure regulator. A water tap should not be used as a pressure regulator because it will not protect the hoses or boom from excessive pressure, nor will it regulate the pressure.

## NONPOSITIVE DISPLACEMENT PUMP

The only type of power take-off sprayer pump that does not displace the liquid positively is the centrifugal pump. Since the liquid is not displaced positively, a pressure regulator does not have to be used with this type of pump; however, a pressure regulator facilitates changing the application rate. Centrifugal pumps must be operated at high speeds to obtain the capacity necessary for a sprayer. The single impeller (single stage) of the centrifugal pump may be run at 3,000 to 6,000 revolutions per minute (rpm) by a pair of gears while the power take-off shaft is turning at 540 rpm. The pump must be mounted below the water level in the tank or a priming system must be incorporated in the sprayer to prime the pump. Centrifugal pumps that are made of abrasion-resistant materials will pump wettable powder suspensions satisfactorily for many years.

NOTE: Never allow a sprayer pump to run dry. Rollers, seals, or bearings may be severely damaged. For specific recommendations, see the manufacturer's instruction sheet or your dealer.

## LINE STRAINERS

The line strainer is in the system to ensure that no small foreign particles reach the pressure regulator and stop it from functioning properly. The screens in the line strainer should be 100 mesh for chemicals in solution or 50 mesh for wettable powder suspensions.

This line strainer could be omitted if the sprayer tank is always entirely free from rust or corrosion, if the water pumped into the sprayer tank is always clean, and if chemicals in solution are used almost exclusively.

## PRESSURE REGULATORS

A pressure regulator is one of the most important parts of a sprayer. The pressure regulator (1) controls the pressure and therefore controls the quantity of spray material delivered by the nozzles and protects pump seals, hoses, and other sprayer parts from damage due to excessive pressure; and (2) by-passes the excess spray material through the by-pass line back to the tank.

There is no substitute for a spring-loaded pressure regulator. Never use a water tap.

When selecting a pressure regulator, be certain that the flow capacity of the regulator matches that of the pump being used. The regulator should be located close to the operator so that the pressure can be adjusted conveniently whenever necessary.

The two main kinds of pressure regulators are the plunger type and the diaphragm type. The plunger may be brass or a stainless steel ball. The spray material, on its way into the by-pass line, comes in contact with the pressure-control spring. This may cause the pressure-control spring to become gummed up or corroded when some wettable powders are used. The brass plunger is rapidly worn by wettable powder suspensions.

The diaphragm type of regulator is more expensive than the plunger type. However, the spray material does not come in contact with the pressure-control spring, and this eliminates the operational difficulties encountered with the plunger type. Usually the parts of the diaphragm pressure-relief valve that are in contact with the spray material are durable and easily replaced.

If the spray pump capacity is too high for the pressure regulator, the pressure regulator may be damaged or overloaded when the boom is shut off. An unloader valve, designed to protect the pressure regulator and pump, should be added to the sprayer system. These unloader valves are available from most sprayer manufacturers either as a separate part or combined with the pressure regulator.

## PRESSURE GAUGE

A pressure gauge is essential on any sprayer--without one, the operator cannot tell how the sprayer is operating. If the pressure does not remain constant, the amount of liquid coming out of the nozzles will vary. Gauges are commercially available that indicate 0-60 psi; 0-100 psi; 0-300 psi... up to 0-1000 psi pressure. If the gauge needle jumps excessively while the sprayer is operating, a surge tank should be added to the sprayer system.

A dampering device may be added to the gauge or the gauge may be replaced by one with less sensitivity. The gauge should always be mounted so that the operator can see it easily. If there is any question about the accuracy of the gauge, it should be tested.

## SELECTOR AND SHUT-OFF VALVES

The selector and shut-off valve allows the operator to conveniently select one to three sections of the boom for spraying a narrow strip in the field, or to shut off all sections of the boom quickly and easily at the end of field. The shut-off valve should always be used at the end of the field to avoid excessive application of chemicals to the headland and to reduce the possibility of drift. The selector valve casting usually has a removable plug in it. The gate valve and piping necessary for spot spraying can then be installed.

## HOSES

The hoses used on sprayers can be the weakest link in the system. High-quality hoses and fittings can be expensive. The garden hose, while less expensive, is not long lasting and often will burst when pump pressure is applied to it. The manufacturers of hoses specify the maximum pressure that can be safely applied. It is best to use hoses that will withstand the maximum pressure that the sprayer pump will supply. A hose that can take no more than 150 psi pressure should never be used.

Select the hose fittings that have as large a bore as possible for the hose used on the sprayer. The least expensive hose fittings are clamped onto the hose in a hydraulic press. These fittings are satisfactory; however, if a hose equipped with these fittings becomes defective, the operator cannot cut the defective piece out of the hose and replace the fitting.

The size of the hose is extremely important. If the hose is too small, the sprayer will not operate properly. The following table lists the minimum size hoze that should be used on a weed sprayer.

| TYPE OF HOSE | HOSE LOCATION | MINIMUM HOSE SIZE (inside diameter) |
|---|---|---|
| Suction hose | tank to pump | 1 to 1 1/4 inch |
| Pressure hose | pump to selector valve | 1/2 inch |
| | pressure regulator to tank (by-pass line) | 1/2 inch |
| | pump to tank (pressure line) | 1/2 inch |
| | selector valve to nozzles | 3/8 inch |

## BOOM SPRAYING

The original weed sprayer booms were made of galvanized or black iron pipe, a constant source of rust flakes that plugged the nozzles. Recently, sprayer booms have been made from copper tubing, aluminum tubing, or rubber hose adequately supported by angle iron. Even though these materials are rust resistant, the end of the boom should be equipped with a removable plug for easy cleaning.

Sprayer booms are commercially available in lengths of 15 to 60 feet. The most common boom length is between 20 and 35 feet. Even with a 20-foot boom, it is essential to have some means of protecting the boom from damage if a tree or other obstacle is encountered. The most common boom is made in three sections--one rigid section in the middle of the machine and a folding section extending out on each side. These outer sections are hinged at their inner ends and are supported from the center of the machine by a rope or light chain. This type of construction gives a 20- to 35-foot boom adequate support, and provides the versatility necessary in irregularly shaped fields and the mobility required when moving the sprayer through narrow gateways.

The height of the sprayer boom must be easily adjustable so the nozzles can deliver the chemical uniformly. Boom supports should be made so the boom can be set at any height from 12 to 48 inches above the surface being sprayed.

If directed sprays are to be used in row crops, a boom with adjustable nozzle spacing is most convenient. The sprayer can be converted easily from an overall sprayer to a row-crop sprayer by merely adding the required drop pipes at the proper intervals.

### RECOMMENDED BOOM HEIGHT FOR FLAT PATTERN NOZZLES

| SPRAY ANGLE | NOZZLE SPACING | HEIGHT OF BOOM ABOVE THE SURFACE TO BE SPRAYED |
|---|---|---|
| 65 degrees | 20 inches | 21 to 23 inches |
| 73 degrees | 20 inches | 20 to 22 inches |
| 80 degrees | 20 inches | 17 to 19 inches |

## BAND SPRAYING

When herbicides are too expensive to apply to the entire field, they are often applied in bands over the row. The herbicide should be applied in the band at the same application rate (in gallons per acre active material per sprayed acre) as recommended for overall spraying. The cost reduction is obtained because only a portion of the field acreage is sprayed.

Band-spraying nozzles (80-degree even-spray nozzles) are usually mounted on the planter so that the row can be kept exactly in the center of the herbicide band. A tractor equipped with saddle tanks is adequate for band spraying.

RECOMMENDED NOZZLE HEIGHT FOR 80-DEGREE EVEN-SPRAY NOZZLES
WHEN THE NOZZLE IS AT RIGHT ANGLES TO THE DIRECTION OF TRAVEL

| BAND WIDTH | APPROXIMATE NOZZLE HEIGHT |
|---|---|
| 6 inches | 4 inches |
| 8 inches | 5 inches |
| 10 inches | 6 inches |
| 12 inches | 7 inches |
| 14 inches | 8 inches |

## DIRECTED SPRAYING

Some herbicides applied directly may damage the crop, but if applied with special nozzle arrangements, can be used to control weeds. For example, linuron, 2,4-D, 2,4-DB, dicamba, MCPA, and MCPB can damage corn at certain stages of growth but are useful in controlling weeds. Drop pipes make it possible to direct the spray onto the weeds under the crop leaves. Drop pipes must be mounted so they are midway between the crop rows. With the nozzles arranged on a swivel or on a cross pipe, the spray can be directed under the crop leaves.

Drop pipes should not be attached rigidly to the boom. A short section of rubber hose near the top of the drop pipe prevents the pipe or the boom from breaking if the ground surface or an obstacle is struck. However, to ensure that the nozzles remain in their proper position in relation to the crop rows, the movement of the nozzles must be restricted by a coil of wire or a spring around the section of hose.

In addition to devices that limit the movement of the nozzles in relation to the crop rows, it is also advantageous to use skids to support the nozzles. The skid arrangement ensures that the nozzles are the same distance from the ground at all times, and that a minimum amount of the herbicide comes in contact with the crop. When the nozzles are supported from the ground, the width of the band sprayed by each nozzle is constant, and crop damage is minimized.

## NOZZLE BODIES

A complete nozzle assembly consists of the body, screen, cap, and tip or orifice plate. The function of the nozzle body is to attach the screen and tip to the boom. Several different nozzle body designs are available. All designs perform adequately, but each design has advantages for specific spraying jobs.

## NOZZLE TIPS

A nozzle is an atomizing device that spreads the liquid droplets in a definite direction to form the spray pattern. Nozzles are made to accommodate a variety of replaceable tips or discs to meet different spraying requirements. Manufacturers of sprayer nozzles can supply data sheets for the delivery rate (usually in gal/min at different pressures for their nozzles).

The application rate CANNOT be specified on these data sheets unless the forward speed of the sprayer and the spraying pressure are specified.

WARNING--Never operate nozzles at high pressures to compensate for selecting the wrong nozzle size. Unnecessarily high pressures increase the rate of nozzle wear and increase the drift hazard.

Nozzle tips and discs are made of aluminum, brass, ceramic, plastic, stainless steel, or tungsten carbide. Tungsten carbide discs and stainless steel tips are more resistant to abrasive wettable powders, but they are more expensive than steel discs and brass tips. No single material is the least expensive, most corrosion resistant, and most durable for spraying all agricultural chemicals.

Nozzles are classified according to the spray pattern as (1) fan or flat pattern, (2) broadcast or boomless, (3) flooding fan, and (4) full cone or hollow cone.

FAN OR FLAT PATTERN NOZZLES

The spray droplets are arranged in a fan shape as they leave the nozzle. The orifice (opening) in this type of nozzle is eliptical. This type of nozzle is best suited to spraying herbicides because:

(1) when a series of these nozzles is properly mounted on a boom, the spray material is more evenly distributed than it would be with any other type of nozzle; and

(2) at 30 to 90 pounds per square inch, the flat-pattern nozzle delivers small to medium droplets that do not drift excessively.

The most commonly used flat-pattern nozzles have a spray angle of 65, 73, or 80 degrees; the most commonly used pressure is 40 psi.

For most herbicide spraying done with a relatively short boom (20 to 35 feet), the 80-degree flat-pattern nozzle is best. It is possible to keep the boom relatively low, reducing the drift hazard, and giving a uniform distribution of spray material over the entire length of the boom.

Special flat-pattern nozzles, usually called even-spray nozzles, are available for band spraying row crops. If a uniform distribution of herbicides is required, these nozzles should not be used.

The flat-pattern nozzle is available in brass, plastic, stainless steel, and hardened stainless steel. The brass nozzle is inexpensive and satisfactory for spraying chemicals in solution. It is not durable enough to spray any more than 20 acres with atrazine. The plastic nozzle is corrosion resistant but should not be used to spray more than 60 acres with atrazine. The stainless steel nozzle is corrosion resistant and durable but should not be used if more than 200 acres are sprayed with atrazine. The hardened stainless steel nozzle is the most durable but it is not as corrosion resistant.

NOTE--When using any wettable powders, it is essential to calibrate the sprayer frequently, because as a nozzle wears, the quantity of spray material delivered INCREASES.

BROADCAST OR BOOMLESS NOZZLE

The broadcast nozzle is made of one or more nozzles in a cluster. These nozzles deliver a flat fan-like pattern that covers a swath up to 70 feet wide. The spray droplets range in size from very small to very large. Broadcast nozzles are convenient for spraying areas in which a uniform distribution of spray material is not essential.

CAUTION--Never use a broadcast type of nozzle when there is any breeze. Severe drifting and crop damage may result.

FLOODING FAN

This is a broadcast-type nozzle that has been modified to be mounted on a boom. The nozzle spacing usually used is 40 to 80 inches. The small- to large-sized spray droplets are not distributed as uniformly as the droplets from a flat-pattern nozzle. The flooding-fan nozzle is available in brass or stainless steel. Its main use is for surface application of liquid fertilizers or for the application of herbicides that are immediately incorporated into the soil.

FULL CONE OR HOLLOW CONE

These two types of nozzles deliver circular patterns. The hollow-cone nozzle delivers most of the material to the circumference of the circle; the full-cone nozzle delivers liquid droplets to the entire area of the circle. The circular opening in the stainless steel, hardened stainless steel, or tungsten carbide disc resists the abrasive action of wettable powders relatively well. The droplets are small or very small and not distributed uniformly when the nozzles are mounted on a boom. The major use of these nozzles is in the application of insecticides or fungicides to field crops where complete coverage of the leaf surfaces is extremely important and where spray drift is relatively unimportant.

SUMMARY OF NOZZLE TYPES AND THEIR USES

| NOZZLE TYPE | DISTRIBUTION OF DROPLETS | MAIN USE | ABRASION RESISTANCE WITH WETTABLE POWDERS |
|---|---|---|---|
| Flat pattern | Uniform when the boom is at the proper height | Herbicides or insecticides | Brass.....poor<br>Plastic.....fair<br>Stainless steel.....good<br>Hardened stainless steel-.....best |
| Broadcast | Not uniform | Herbicides in waste places | Good but not often used with wettable powders |
| Flooding fan | Not as uniform as flat pattern | Liquid fertilizer and pre-plant incorporated herbicides | Likely good, but not often used with wettable powders |
| Full cone or Hollow cone | Not uniform when used on a boom | Insecticides or fungicides | Relatively good |

## NOZZLE SCREENS

The screen is placed behind the nozzle tip and in the nozzle body to help eliminate, or at least reduce, the frequency with which the nozzle orifice becomes plugged. The size of the nozzle opening and/or the type of chemical being sprayed dictate the size and type of nozzle screen that should be used. For most general herbicide spraying, a 100-mesh monel or stainless steel nozzle screen can be used. When wettable-powder suspensions are being applied, a 50-mesh monel or stainless steel nozzle screen should be used.

When the boom must be turned off frequently--in small fields or when the crop may be damaged by an overdose of chemical--nozzle "dribble" may be a serious problem. A nozzle screen with a check valve in it will help eliminate dribble and will not affect the operation of the sprayer. Some care must be taken to make certain that the ball bearing does not become glued to its seat or that dirt or chemical particles do not hold the ball bearing off its seat.

## WEED SPRAYER OPERATION

### SPRAYER CALIBRATION
(Determining the sprayer output per acre)

To calibrate a sprayer means to determine the number of gallons of spray material that are being applied to an acre of land. A straight forward method with relatively simple calculations follows:

(1) Set out two stakes 330 feet (20 rods) apart in the field.

(2) Pick a level spot and fill the sprayer tank with water. Operate the sprayer to be sure that the supply line to the shut-off valve is full before finally filling the tank. Record the water level on a measuring stick.

(3) Spray between stakes in both directions at a definite speed and pressure. Turn the boom on as you pass the first stake in each direction, and turn the boom off as you pass the last stake in each direction. The by-pass pressure relief valve must be set to give the desired pressure when the nozzles are operating. The forward speed can be found by determining the time required to drive 330 feet and using the following table:

TIME REQUIRED TO TRAVEL 330 FEET AT VARIOUS FORWARD SPEEDS

| Time | | |
|---|---|---|
| Minutes | Seconds | Forward speed miles per hour |
| 3 | 45 | 1 |
| 1 | 52 | 2 |
| 1 | 15 | 3 |
| | 56 | 4 |
| | 45 | 5 |
| | 37 | 6 |

(An easier way to determine the exact forward speed is to mount a low-speed speedometer on the tractor or trailing sprayer.) Note the forward speed and use the same while spraying.

NOTE--It is imperative to maintain the same pressure and the same forward speed during the calibration of the sprayer that will be used in the field.

(4) Return the sprayer to the same location as before the calibration run. Carefully measure the amount of water required to refill the tank to the same mark on the measuring stick.

(5) Calculate the application rate in gallons per acre (gal/A) using this formula:

$$\text{gal/A} = \frac{\text{gallons of water added} \times 66}{\text{boom length (in feet)}}$$

For example, if the sprayer has a 25-foot boom and if the tank required 12 gallons of water to be refilled, the application rate is:

$$\text{gal/A} = \frac{12 \times 66}{25} = 31.7$$

Here is an example for band spraying:

If the sprayer has 4 nozzles and each nozzle covers a 14-inch band, the total width of the spray patterns (boom length) is:

$$\frac{4 \times 14}{12} = 4.7 \text{ feet}$$

and if 2 gallons of water are required to refill that tank, the application rate is:

$$\text{gal/A} = \frac{2 \times 66}{4.7} = 28.1$$

NOTE--When band spraying, the acreage actually sprayed is not the same as the field acreage.

After the rate of spray application has been calculated, the amount of herbicide product to add to the tank must be determined. When a recommendation is given in "active" ingredient, an adjustment must be made for the "non-active" ingredient in the product. The active ingredient in ounces (or pounds) per gallon or in a percentage will be found on the label of the product container.

Two simple formulae allow the conversion of active ingredient to gallons or pounds of commercial product. If the active ingredient is indicated on the product label in pounds per gallon, use this formula:

$$\text{gallons of commercial product per acre} = \frac{\text{pounds active ingredient recommended per acre}}{\text{pounds active ingredient per gallon (see label)}}$$

If the active ingredient is indicated on the product label in a percentage, then use this formula:

$$\text{pounds of commercial products per acre} = \frac{\text{pounds active ingredient recommended per acre} \times 100}{\text{active ingredient in percent (see label)}}$$

Sample Calculation: If 1 pound per acre of 2,4-D (acid equivalent) active ingredient is recommended, and the product label states that there are 4 pounds of acid equivalent per gallon, then:

$$\text{gallons of commercial product per acre} = \frac{1 \text{ pound}}{4 \text{ pounds}} = .25 \text{ gallon or 1 quart}$$

Therefore, 1 quart (32 fluid ounces) of the 2,4-D product must be added to the number of gallons of solution applied by the sprayer to each acre.

If 2 pounds per acre of atrazine active ingredient are recommended, and the label states that the product contains 80 percent active atrazine, then:

$$\text{pounds of commercial product per acre} = \frac{2 \times 100}{80} = 2.5$$

Therefore, 2.5 pounds of the atrazine product must be added to the number of gallons applied by the sprayer to each acre.

## USEFUL FORMULAE

It is often useful to know the rate at which the boom is delivering the spray material. Boom output in gal/min can be determined in several ways. The sprayer could be operated for a definite period of time (perhaps 5 minutes) and the tank refilled to its original level. The boom output in gal/min would then be the number of gallons required to refill the tank, divided by 5. However, since the sprayer has already been calibrated by driving 660 feet at a definite speed, the boom output in gal/min can be calculated by using the formula:

$$\text{boom output (in gal/min)} = \frac{\text{gal/A} \times \text{mph} \times \text{boom length (in feet)}}{495}$$

Sample Calculation: If the sprayer applied 31.7 gal/A at 4 mph through a 25-foot boom, what is the boom output in gal/min?

$$\text{boom output} = \frac{31.7 \times 4 \times 25}{495} = 6.43 \text{ gal/min}$$

When the boom output in gal/min is known, the formula can be switched around to let the operator determine the correct forward speed for any desired application rate in gal/A.

$$\text{mph} = \frac{\text{boom output (in gal/min)} \times 495}{\text{boom length (in feet)} \times \text{gal/A}}$$

Sample Calculation: How fast should a sprayer be driven when the boom output is 6.43 gal/min, the boom is 25 feet long and the desired application rate is 42.5 gal/A?

$$\text{mph} = \frac{6.43 \times 495}{25 \times 42.5} = 3$$

Finally, the formula can be switched around to let the operator determine the application rate in gal/A when the boom output, forward speed, and boom length are known. This is another way, often called the time method, of calibrating a sprayer.

$$\text{gal/A} = \frac{\text{boom output (in gal/min)} \times 495}{\text{boom length (in feet)} \times \text{mph}}$$

Sample Calculation: If the boom output is 6.43 gal/min, the boom length is 25 feet, and the sprayer is driven at 4 mph, what is the application rate in gal/A?

$$\text{gal/A} = \frac{6.43 \times 495}{25 \times 4} = 31.7$$

## OPERATING PRECAUTIONS

1. Never use a pin, knife, or other metal object to unplug a nozzle. Use compressed air, an old toothbrush, or a brush with soft bristles. Never blow into a nozzle to clean it.
2. Never allow dirty water or debris to enter the tank.
3. Control spray drift by:
   (a) using the largest nozzles and the lowest pressure that will apply the herbicide properly.
   (b) keeping the boom as low as permissable.
   (c) spraying on days without wind or breeze.
4. Do not use corrosive fertilizer solutions in an ordinary weed sprayer. Parts made of brass, copper, steel, aluminum, or even galvanized materials may be severely damaged, unless the sprayer is cleaned carefully.
5. Never operate a sprayer with any of the screens or filters removed. If the screen constantly becomes plugged, replace it with a screen of the proper mesh and capacity.
6. Never fasten a power take-off driven pump solidly to the tractor. The chain provided will keep most sprayer pumps from rotating. Fastening the pump with a bar usually causes rapid bearing wear.
7. Never allow any sprayer pump to run without water, even for a short time; pump seals, bearings, and other working parts may be severely damaged.
8. Never leave a pesticide solution in a tank for prolonged periods (overnight or longer). Wettable powders settle rapidly and are difficult to re-suspend. Some materials become chemically changed, especially if mixtures are present.
9. Always pump at least 50 gallons of clean water through the sprayer at the end of the day or when changing from one herbicide to another. Clean all nozzle tips and screens at the same time. This helps reduce the gummy deposits or the accumulations of wettable powders in the sprayer.
10. Air-blast or mist sprayers are designed to apply insecticides and/or fungicides. They should never be used to apply herbicides, especially hormone-type herbicides such as 2,4-D.

## CLEANING THE SPRAYER

There is no satisfactory way to completely remove all traces of any herbicide from a sprayer. Traces of chemicals in solution (2,4-D, etc.) cannot be completely removed from porous tanks (wooden, unlined steel, etc.), hoses, pressure regulators, selector valves, and screens. If a herbicide sprayer must be used to apply an insecticide or fungicide, do not apply the insecticide or fungicide to a crop that may be damaged by the herbicide. Chemicals in suspension (atrazine, etc.) may not be as difficult to remove from the sprayer, but traces may still be present unless all parts are thoroughly cleaned.

## END-OF-THE-DAY CLEANING

Whenever wind or weather conditions force you to temporarily stop spraying, clean the sprayer to prevent gum or powder deposits in the pressure regulator, selector valve, nozzle tips, and screens.

Follow these steps:

1. Rinse the inside and outside of the tank with plenty of clean water.
2. Fill the tank half way with clean water and spray it out at low pressure. While the sprayer is operating, run the bilge pump, adjust the pressure regulator and the selector valve, and remove the plugs in the ends of the three boom sections. A small amount of liquid detergent added to the water will help clean the inside of the sprayer system.
3. Clean the nozzles, nozzle screens, and suction screens with compressed air or a soft brush. Replace the screens and nozzles.
4. Leave the tank full of clean water if weather conditions permit.

CAUTION--Never clean a sprayer near susceptible plants or where the wash water could contaminate farm ponds, streams, or other supplies of water.

## STORING THE SPRAYER

When you store your sprayer properly, you add years to its useful life.

1. Clean the sprayer thoroughly.
2. Completely lubricate all moving parts according to the manufacturer's recommendations.
3. Make a list of all faulty parts and order the new ones to be ready for the following spring.
4. Fill the tank with water and add the recommended quantity and type of rust inhibitor or new light oil (see your instruction manual). Drain the tank. Leave all tank openings uncovered for ventilation, but screen them to keep out dust and debris.
5. Clean all nozzle tips and screens with compressed air or a soft brush and kerosene. Store the tips and screens in a jar of new light oil or kerosene.
6. Take the weight off of any tires.
7. Remove, clean and drain the pump. Fill it with the light oil or rust inhibitor recommended by the pump manufacturer. Seal all pump openings to keep out dust and dirt.

NOTE--Make certain that no water is left in the pressure regulator, selector valve, or the boom. These parts will be severely damaged if water freezes in them.

## SOME COMMON WEED SPRAYER TROUBLES

| PROBLEM | CAUSE | REMEDY |
|---|---|---|
| Loss of Pressure | 1. Pressure regulator improperly adjusted or stuck open | 1. Adjust pressure regulator. |
| | 2. Suction screen plugged | 2. Clean screen thoroughly. |
| | 3. Suction hose cracked or porous | 3. Replace hose. |
| | 4. Pump worn | 4. Replace or recondition pump according to the manufacturer's instructions. |
| | 5. Nozzle tips or orifices worn | 5. Replace nozzle tips or orifices. |
| | 6. Gauge faulty | 6. Replace gauge. |
| Excessive Pressure | 1. Pressure regulator improperly adjusted or stuck closed | 1. Adjust pressure regulator. |
| | 2. By-pass hose plugged or too small | 2. Unplug the hose or replace it with a larger one. |
| | 3. Gauge faulty | 3. Replace gauge. |
| Pressure gauge needle jumps excessively | 1. Gauge too sensitive | 1. Replace gauge or mount a flow restrictor or needle valve between the gauge and the pump. |
| | 2. Air cushion for the surges in liquid flow is gone (surge tank is waterlogged) | 2. Admit air into the pump's air chamber, or install an air chamber on the pressure side of the pump. |
| Plugged nozzles | 1. Nozzle screen too coarse | 1. Replace with the proper mesh screen. |
| | 2. Water, chemical, or tank not clean | 2. Drain tank and clean thoroughly; check suction screen for holes. |
| | 3. Nozzles too small | 3. Replace with the proper nozzles for the chemical being used. |
| | 4. Boom plugged | 4. Remove the plugs in the ends of the boom section to clean the boom. |

## AIR BLAST SPRAYING FOR ROW CROPS

Two types of row-crop air-blast sprayers are available; the one-way turntable outlet and the fixed two-way discharge. Each has advantages. The advantages of the one-way outlet are limited to the smaller machines (up to 60 foot swath). For swath widths of more than 60 feet, only the two-way sprayer will consistently deliver the pesticide deposits required to justify the investment in the larger machines.

Total air-jet throw is 40 percent greater when a given volume of air (at the same velocity) is divided and discharged from two outlets in opposite directions.

Pesticide should be driven into the foliage with turbulent force. Larger one-way sprayers depend on the wind to drift the swath to its advertised width. Spraying with the wind usually results in the deposit being dropped onto the foliage, rather than driven into it.

The following table gives the time required for various droplet diameters (density 1.0) to fall 50 feet in still air at 74° F.

| DIAMETER (MICRONS) | TIME |
|---|---|
| 200 | 13 seconds |
| 100 | 51 seconds |
| 80 | 1.3 minutes |
| 50 | 3.4 minutes |
| 40 | 5.2 minutes |
| 20 | 21 minutes |
| 10 | 1.4 hours |
| 5 | 5.5 hours |
| 1 | 5 days |

Notice that a droplet of 200 microns will fall 50 feet in one-fourth the time that 100-micron droplet will fall. The rate of fall is the same whether the droplet is in still air or if it is carried by a horizontally moving air column. Vertical convection and inversion air currents will affect the rate of fall and affect row crop spraying on hot days.

A 200-micron droplet contains 8 times the pesticide contained in the 100-micron droplet. The fact that it will settle out of the air stream 4 times faster means that it will be deposited at one-fourth the distance of the 100-micron droplet. This wide difference between droplet mass and carry shows the importance of good atomization for even spray distribution across the air swath.

## EFFECT OF AIR OUTLET SHAPE

The jet of high velocity air being discharged is in effect a venturi: surrounding free air is being drawn into this jet stream, reducing the velocity of the air pattern.

Hydraulically, the most efficient outlet shape (if desired pattern could be obtained) is a circular outlet. The circular outlet has a higher hydraulic diameter, and therefore it has a lower entrainment ratio than long narrow outlets of equivalent area.

The longer an outlet in relation to its width, the greater the induction of free air surrounding the outlets. The more air induced into the jet stream, the greater the reduction in jet velocity; this creates a decrease in air jet throw.

The outlet of two-way air machines is a compromise between the ideal (circular) nozzle and a long narrow outlet. For most sprayers, the main portion of the two-way outlet is square with a lower zone which is a diffusing section. This diffused low-velocity air eliminates crop blow-down in the rows adjacent to the sprayer.

## AIR OUTLET LOCATION

Wind velocity is lowest near the ground, and it increases with height. Angling discharge vanes down to immediately get the air discharge out of this high velocity area will consistently produce wider spray swaths in windy conditions. The rolling pattern which is created gives superior coverage on both sides of the leaf.

## OPERATIONAL PROCEDURES OF AIR ROW CROP SPRAYING

Many factors have to be considered when determining the work rate of row crop air sprayers. Variables such as type of crop, ground speed, wind, water availability, field size, and row length influence cover rate.

Weather, chemical effectiveness, and the operator's skill are as important as the sprayer's performance.

The three most common mistakes in air spraying techniques are:

1. Excessive rates of travel
2. Over-extension of swath reach
3. Lateral rather than downward discharge

## RATE OF TRAVEL

The correct rate of travel is important since the translational effect of relative air has an effect on the total swath reach.

Generally, the rate of travel should be limited to 1 1/2 to 2 mph. An applicator should frequently check the deposit over the swath to make sure that sufficient coverage is being obtained. If coverage is questionable, the rate of travel or the drive row spacing should be changed.

In extremely flat areas, applicators may resort to night spraying to reduce the wind factor. This may not always be practical, but certainly extends the availability of equipment. A spotlight, mounted above the air outlet and directed laterally, allows a continual visual check of the spray swath.

Air-pattern control vanes should be adjusted to direct the air jet downward under the wind and into the foliage. Many applicators have found that they obtain consistently longer swaths this way and no longer need to make in-travel adjustments of the vane angle.

## SPRAY VOLUME

The amount of water used in dilution is based on the gallonage applied per acre with a hydraulic boom. The gallonage for hydraulic booms, commonly called a "dilute application," is determined as the number of gallons per acre required to wet the foliage to the point of run-off.

The "dilute" gallonage per acre varies between crops as well as between areas. There is no set standard. A rate of 160 gal/A has been generally accepted as a "dilute" application for potatoes, tomatoes, sugar beets, and similar crops.

With air-blast sprayers, the amount of water required has been successfully reduced to 1/4 to 1/10 "dilute" spray gallonage. Applicators can use between 10 and 40 gal/A per spray treatment.

The most commonly used dilution is 40 gal/A. Although fine droplets are necessary to obtain adequate distribution with low gallonages, they must be large enough to give a deposit on foliage. This balance between droplet diameter and deposit obtained will probably continue to establish the practical minimum water requirements in the 10-gal/A range.

## DRIFT HAZARD

Spray drift can be a hazard to both the operator and to other persons in the area. Normally row crops are grown in large acreages, which should minimize the drift problem.

Two operational techniques will keep drift hazard to a minimum. First, by angling the air pattern into the foliage, the smaller droplets will more readily stick to foliage. This reduces the possibility of wind currents carrying the smaller droplets into populated areas. Secondly, the plot should be opened by driving completely around the field, spraying from one side of the machine toward the center. This technique eliminates misses in the turnaround area and provides a buffer zone to reduce spray fallout outside the field boundary.

The distance that a droplet 100 microns in diameter, will drift while falling 5 feet are as follows:

| WIND (MILES PER HOUR) | DRIFT (FEET) |
|---|---|
| 1/4 | 2.2 |
| 1/2 | 4.5 |
| 1 | 8.7 |
| 2 | 17.5 |
| 3 | 26.0 |
| 4 | 34.8 |
| 5 | 43.5 |
| 10 | 76.5 |

Droplets of 100 microns and larger will not present a problem if a 60 foot buffer zone is sprayed first around the field.

Droplets smaller than 100 microns can drift considerable distances, as shown in this table:

| DIAMETER OF DROPLET (MICRONS) | | DISTANCE TRAVELLED* (FEET) |
|---|---|---|
| 1000 | (Moderate rain) | 2.5 |
| 500 | (Light rain) | 3.75 |
| 300 | | 5.0 |
| 200 | (Drizzle) | 9.0 |
| 100 | (Mist) | 26.0 |
| 50 | | 100.0 |
| 30 | (Cloud) | 250.0 |
| 15 | (Coarse Aerosol) | 1000.0 |
| 5 | (Sea fog) | 10,500.0 |

*Distance travelled while settling 5 feet in air flow averaging 3 mph.

DRIVING TECHNIQUE

The diagram on page 23 shows the method recommended for use with two-way sprayers. The field is opened by making a complete pass around the field, discharging from one side only. The balance of the field is then sprayed, discharging from both sides.

For one-way turntable-mounted sprayers, most operators advise that maximum utilization be made of the blower by an angular position of the discharge, depending on the wind direction. Some one-way sprayers have a total rotation of 210 degrees, which gives 15 degrees lead on either side. To reduce the translational loss of swath throw, the blower is aimed into the wind when travelling with it. Travelling into the wind, the discharge head is directed away from the wind.

An opening spray pass completely around the field is recommended also for the one-way field crop sprayer.

## SPRAYER CALIBRATION

To determine total nozzle-discharge rate of the sprayer, three factors must be known:

1. Swath width
2. Gallonage to be applied per acre
3. Rate of travel

With these three factors and the following formulae, the nozzle rate can be determined:

$$\text{feet of travel per acre} = \frac{43{,}560}{\text{swath width (feet)}}$$

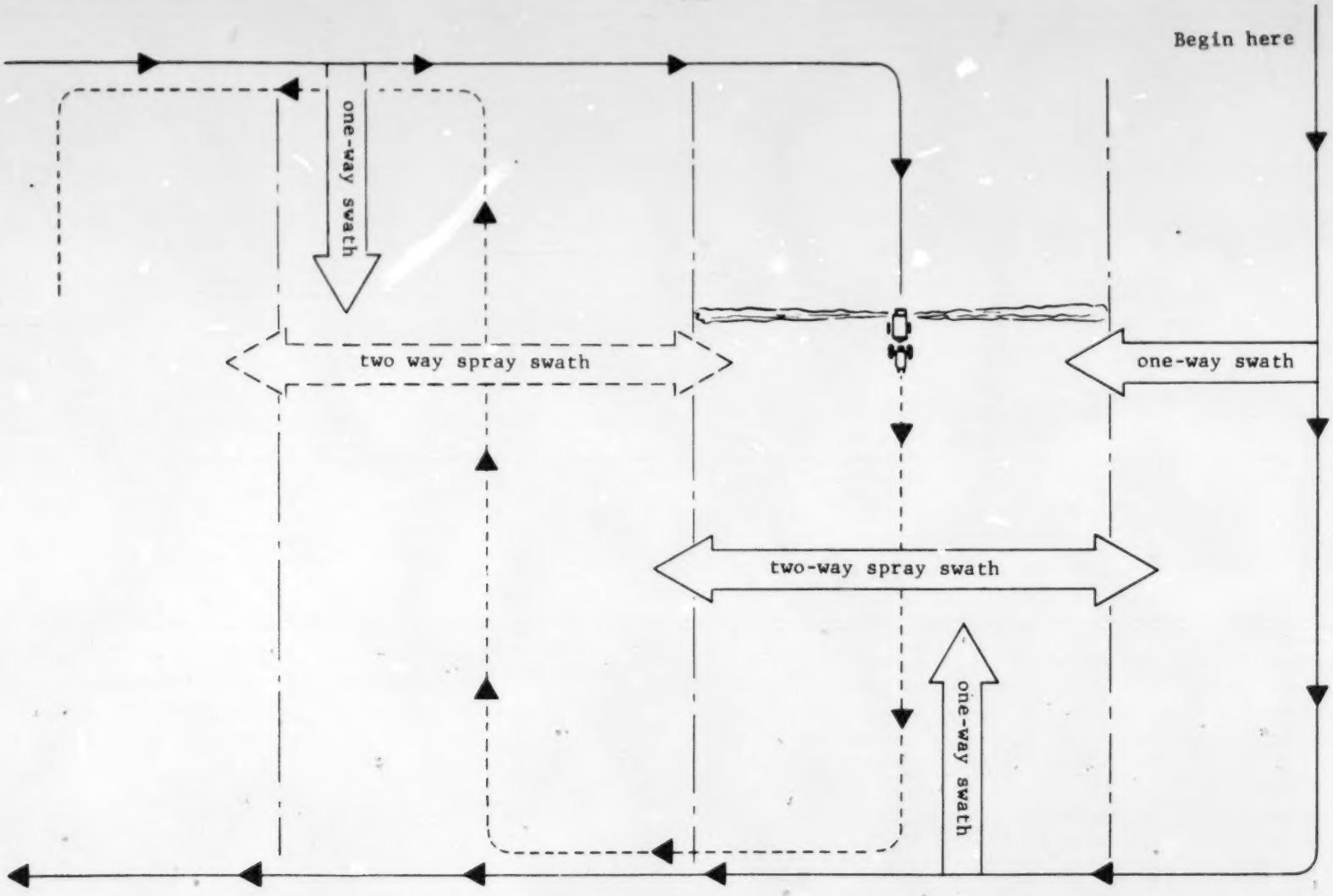
$$\text{rate of travel in feet per minute} = \text{travel rate (mph)} \times 88$$

$$\text{minutes per acre} = \frac{\text{feet of travel per acre}}{\text{rate of travel (ft per min)}}$$

$$\text{gallons per minute discharge from sprayer} = \frac{\text{gallonage per acre}}{\text{minutes per acre}}$$

For example:

Assume that you want to apply 40 gallons per acre of 4X concentrate (previous dilute rate was 160 gallons per acre. The swath width is




RECOMMENDED METHOD OF SPRAYING
WITH A TWO-WAY FIELD CROP AIR SPRAYER

110 feet and the rate of travel will be 2 miles per hour.

$$\text{feet of travel per acre} = \frac{43{,}560}{110} = 396$$

$$\text{feet per minute rate of travel} = 2 \times 88 = 176$$

$$\text{minutes per acre} = \frac{396}{176} = 2.25$$

$$\text{gallons per minute} = \frac{40}{2.25} = 17.8$$

If the discharge rate is fixed, such as on a sprayer with a reciprocating pump, the rate of travel will have to be varied to give the desired application rate. In this statement, we use the following formulae in sequence:

$$\text{feet of travel per acre} = \frac{43{,}560}{\text{swath width}}$$

$$\text{minutes per acre} = \frac{\text{gallonage to be applied per acre}}{\text{nozzling of sprayer (gallons per minute)}}$$

$$\text{travel rate in feet per minute} = \frac{\text{feet of travel per acre}}{\text{minutes per acre}}$$

$$\text{travel rate in miles per hour} = \frac{\text{travel rate in feet per minute}}{88}$$

Example: Assume here that you have a sprayer equipped with a 25-gal/min reciprocating pump. To prevent a pressure drop and consequent poor atomization, you will nozzle the sprayer at about 90 percent of pump capacity, approximately 22 gallons per minute. Swath width will be 110 feet and desired application rate will be 40 gallons per acre.

$$\text{feet of travel per acre} = \frac{43{,}560}{110} = 396$$

$$\text{minutes per acre} = \frac{40}{22} = 1.82$$

$$\text{feet per minute rate of travel} = \frac{396}{1.82} = 218$$

$$\text{rate of travel in miles per hour} = \frac{218}{88} = 2.48 \text{ or } 2.5$$

The following table gives ground speeds and application rates for 30- to 110-foot swaths at nozzle discharge rates of 5 to 40 gal/min. By picking the column which applies to your swath coverage, the correct rate of travel can readily be determined if the application rate per acre and nozzle discharge of the sprayer are known.

## GALLONS PER ACRE

| Swath Width (ft) | Ground Speed (mph) | Application Time (min/A) | Total Nozzle Discharge in Gallons Per Minute: 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Gallons Applied Per Acre | | | | | | | |
| 110 | 4 | 1.13 | 5.7 | 11.3 | 17.0 | 22.6 | 28.3 | 33.9 | 39.6 | 45.2 |
| | 3½ | 1.29 | 6.5 | 12.9 | 19.4 | 25.8 | 32.3 | 38.7 | 45.2 | 51.6 |
| | 3 | 1.50 | 7.5 | 15.0 | 22.5 | 30.0 | 37.5 | 45.0 | 52.5 | 60.0 |
| | 2½ | 1.80 | 9.0 | 18.0 | 27.0 | 36.0 | 45.0 | 54.0 | 63.0 | 72.0 |
| | 2 | 2.25 | 11.3 | 22.5 | 33.8 | 45.0 | 56.3 | 67.5 | 78.8 | 90.0 |
| 80 | 4 | 1.55 | 7.8 | 15.5 | 23.3 | 31.0 | 38.8 | 46.5 | 54.3 | 62.0 |
| | 3½ | 1.77 | 8.9 | 17.7 | 26.3 | 35.4 | 44.3 | 53.1 | 62.0 | 70.8 |
| | 3 | 2.06 | 10.3 | 20.6 | 30.9 | 41.2 | 51.5 | 61.8 | 72.1 | 82.4 |
| | 2½ | 2.48 | 12.4 | 24.8 | 37.2 | 49.6 | 62.0 | 74.4 | 86.8 | 99.2 |
| | 2 | 3.09 | 15.5 | 30.9 | 46.4 | 61.8 | 77.3 | 92.7 | 108.2 | 123.6 |
| 70 | 4 | 1.77 | 8.9 | 17.7 | 26.6 | 35.4 | 44.3 | 53.1 | 62.0 | 70.8 |
| | 3½ | 2.02 | 10.1 | 20.2 | 30.3 | 40.4 | 50.5 | 60.6 | 70.7 | 80.8 |
| | 3 | 2.36 | 11.8 | 23.6 | 35.4 | 47.2 | 59.0 | 70.8 | 82.6 | 94.4 |
| | 2½ | 2.83 | 14.2 | 28.3 | 42.5 | 56.6 | 70.8 | 84.9 | 99.0 | 113.2 |
| | 2 | 3.54 | 17.7 | 35.4 | 53.1 | 70.8 | 88.5 | 106.2 | 123.9 | 141.6 |
| 60 | 4 | 2.06 | 10.3 | 20.6 | 30.9 | 41.2 | 51.5 | 61.8 | 72.1 | 82.4 |
| | 3½ | 2.36 | 11.8 | 23.6 | 35.4 | 47.2 | 59.0 | 70.8 | 82.6 | 94.4 |
| | 3 | 2.75 | 13.8 | 27.5 | 41.3 | 55.0 | 68.8 | 82.5 | 96.3 | 110.0 |
| | 2½ | 3.30 | 16.5 | 33.0 | 49.5 | 66.0 | 82.5 | 99.0 | 115.5 | 132.0 |
| | 2 | 4.13 | 20.7 | 41.3 | 62.0 | 82.6 | 103.3 | 123.9 | 144.6 | 165.2 |
| 55 | 4 | 2.25 | 11.3 | 22.5 | 33.8 | 45.0 | 56.3 | 67.5 | 78.8 | 90.0 |
| | 3½ | 2.57 | 12.9 | 25.7 | 38.6 | 51.4 | 64.3 | 77.1 | 90.0 | 102.8 |
| | 3 | 3.00 | 15.0 | 30.0 | 45.0 | 60.0 | 75.0 | 90.0 | 105.0 | 120.0 |
| | 2½ | 3.60 | 18.0 | 36.0 | 54.0 | 72.0 | 90.0 | 108.0 | 126.0 | 144.0 |
| | 2 | 4.50 | 22.5 | 45.0 | 67.5 | 90.0 | 112.5 | 135.0 | 157.5 | 180.0 |
| 50 | 4 | 2.48 | 12.4 | 24.8 | 37.2 | 49.6 | 62.0 | 74.4 | 86.8 | 99.2 |
| | 3½ | 2.83 | 14.2 | 28.3 | 42.5 | 56.6 | 70.8 | 84.9 | 99.1 | 113.2 |
| | 3 | 3.30 | 16.5 | 33.0 | 49.5 | 66.0 | 82.5 | 99.0 | 115.5 | 132.0 |
| | 2½ | 3.96 | 19.8 | 39.6 | 59.4 | 79.2 | 99.0 | 118.8 | 138.6 | 158.4 |
| | 2 | 4.95 | 24.8 | 49.5 | 74.3 | 99.0 | 123.8 | 148.5 | 173.3 | 198.0 |
| 42 | 4 | 2.95 | 14.8 | 29.5 | 44.3 | 59.0 | 73.8 | 88.5 | 103.3 | 118.0 |
| | 3½ | 3.37 | 16.9 | 33.7 | 50.6 | 67.4 | 84.3 | 101.1 | 118.0 | 134.8 |
| | 3 | 3.93 | 19.7 | 39.3 | 59.0 | 78.6 | 98.3 | 117.9 | 137.6 | 157.2 |
| | 2½ | 4.72 | 23.6 | 47.2 | 70.8 | 94.4 | 118.0 | 141.6 | 165.2 | 188.8 |
| | 2 | 5.89 | 29.5 | 58.9 | 88.4 | 117.8 | 147.3 | 176.7 | | |
| 40 | 4 | 3.09 | 15.5 | 30.9 | 46.4 | 61.8 | 77.3 | 92.7 | 108.2 | 123.6 |
| | 3½ | 3.54 | 17.7 | 35.4 | 53.1 | 70.8 | 88.5 | 106.2 | 123.9 | 141.6 |
| | 3 | 4.13 | 20.7 | 41.3 | 62.0 | 82.6 | 103.3 | 123.9 | 144.6 | 165.2 |
| | 2½ | 4.95 | 24.8 | 49.5 | 74.3 | 99.0 | 123.8 | 148.5 | 173.3 | 198.0 |
| | 2 | 6.19 | 31.0 | 61.9 | 92.9 | 123.8 | 154.8 | 185.7 | | |
| 36 | 4 | 3.44 | 17.2 | 34.4 | 51.6 | 68.8 | 86.0 | 103.2 | 120.4 | 137.6 |
| | 3½ | 3.93 | 19.7 | 39.3 | 59.3 | 78.6 | 98.3 | 117.9 | 137.6 | 157.2 |
| | 3 | 4.58 | 22.9 | 45.8 | 68.7 | 91.6 | 114.5 | 137.4 | 160.3 | 183.2 |
| | 2½ | 5.50 | 27.5 | 55.0 | 82.5 | 110.0 | 137.5 | 165.0 | 192.5 | |
| | 2 | 6.88 | 34.4 | 68.8 | 103.2 | 137.6 | 172.0 | | | |
| 30 | 4 | 4.13 | 20.7 | 41.3 | 62.0 | 82.6 | 103.3 | 123.9 | 144.6 | 165.2 |
| | 3½ | 4.72 | 23.6 | 47.2 | 70.8 | 94.4 | 118.0 | 141.6 | 165.2 | 188.8 |
| | 3 | 5.50 | 27.5 | 55.0 | 82.5 | 110.0 | 137.5 | 165.0 | 192.5 | |
| | 2½ | 6.60 | 33.0 | 66.0 | 99.0 | 132.0 | 165.0 | 198.0 | | |
| | 2 | 8.25 | 41.3 | 82.5 | 123.8 | 165.0 | | | | |

Compiled from various sources by Herbert Cole, Jr., Professor, Plant Pathology. Some material adapted from "Field Weed Sprayers," Publication 256, Ontario Department of Agriculture and Food.

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